

TNO Defence Research

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J.H. Kerstholt

LEARNING EFFECTS ON STRATEGY
SELECTION IN A DYNAMIC TASK
ENVIRONMENT AS A FUNCTION OF TIME
PRESSURE

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Netherlands organization for
applied scientific research

TNO Defence Research consists of:
the TNO Physics and Electronics Laboratory,
the TNO Prins Maurits Laboratory and the
TNO Institute for Perception



Korte samenvatting van:

Learning effects on strategy selection in a dynamic task environment as a function of time pressure (Het effect van training op de selectie van een beslissstrategie in een dynamische taakomgeving als functie van tijdsdruk)

J.H. Kerstholt

21 juni 1994, Rapport TNO-TM 1994 B-12

TNO Technische Menskunde¹, Soesterberg

MANAGEMENT UITTREKSEL

Previous research on strategy selection in dynamic task environments indicated that subjects preferred to request information first, before an action was applied, even when the straightforward application of actions would have resulted in more optimal performance. Furthermore, this strategy was also used when subjects only had limited time for diagnosis. In the present experiment it was investigated whether the amount of training could account for the limited use that subjects made of the task dynamics. Subjects were required to monitor the changing fitness level of an athlete, by means of a graph on a computer screen, and to apply treatments whenever necessary. They could request various symptoms that would provide an indication for the cause underlying a possible fitness decline. The subjects either received limited training or elaborate training and they had either sufficient time for diagnosis, or worked under time pressure.

The results showed that the amount of training did not affect the strategy that subjects used: half of the subjects used a judgment-oriented strategy and the other half used an action-oriented strategy in both training conditions. However, the well trained subjects were superior in selecting information and they processed the information at a faster rate than the subjects with only minimal training. The time pressure effects replicated previous findings: subjects used the same strategy and speeded up information processing. A high level of time pressure only deteriorated the information integration processes of the subjects who had received only minimal training, but not that of the well-trained subjects.

The findings suggest that training alone, without any instructions on how to deal with the task, does not result in the selection of an optimal decision strategy, posing limitations to the adaptivity of decision making behaviour in a dynamic task environment. Furthermore, the results suggest that elaborate training can overcome negative time pressure effects, especially with respect to the integration of information.

¹ Per 1 februari 1994 is de naam Instituut voor Zintuigfysiologie TNO gewijzigd in TNO Technische Menskunde.

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SUMMARY

Previous research on strategy selection in dynamic task environments indicated that subjects preferred to request information first, before an action was applied, even when the straightforward application of actions would have resulted in more optimal performance. Furthermore, this strategy was also used when subjects only had limited time for diagnosis. In the present experiment it was investigated whether the amount of training could account for the limited use that subjects made of the task dynamics. Subjects were required to monitor the changing fitness level of an athlete, by means of a graph on a computer screen, and to apply treatments whenever necessary. They could request various symptoms that would provide an indication for the cause underlying a possible fitness decline. The subjects either received limited training or elaborate training and they had either sufficient time for diagnosis, or worked under time pressure. The results showed that the amount of training did not affect the strategy that subjects used: half of the subjects used a judgment-oriented strategy and the other half used an action-oriented strategy in both training conditions. However, the well trained subjects were superior in selecting information and they processed the information at a faster rate than the subjects with only minimal training. The time pressure effects replicated previous findings: subjects used the same strategy and speeded up information processing. A high level of time pressure only deteriorated the information integration processes of the subjects who had received only minimal training, but not that of the well-trained subjects. The findings suggest that training alone, without any instructions on how to deal with the task, does not result in the selection of an optimal decision strategy, posing limitations to the adaptivity of decision making behaviour in a dynamic task environment. Furthermore, the results suggest that elaborate training can overcome negative time pressure effects, especially with respect to the integration of information.

Het effect van training op de selectie van een beslisstrategie in een dynamische taakomgeving als functie van tijdsdruk

J.H. Kerstholt

SAMENVATTING

Voorgaand onderzoek naar de beslisstrategieën die in dynamische taken worden gebruikt, heeft aangetoond dat proefpersonen bij voorkeur eerst informatie opvragen voordat zij een actie uitvoeren, zelfs in taken waar het louter uitvoeren van acties tot een betere uitkomst zou hebben geleid. Een dergelijke diagnostische strategie werd ook gebruikt als de proefpersonen slechts weinig tijd hadden voor het nemen van een beslissing. In het huidige experiment werd onderzocht in hoeverre de hoeveelheid training een invloed heeft op de mate waarin men gebruik maakt van de continue feedback over de toestand van het systeem. Proefpersonen moesten het veranderende conditieniveau van een atleet in de gaten houden en, indien dit nodig was, moesten zij ook behandelingen geven aan de atleet. De proefpersonen konden verschillende symptomen opvragen, hetgeen een indicatie verschafte voor de oorzaak van de conditieverslechtering. De helft van de proefpersonen kreeg slechts een beperkte training en de andere helft van de proefpersonen kreeg een uitgebreidere training. Zij werkten ofwel onder tijdsdruk, of zij hadden voldoende tijd voor een diagnose.

De resultaten tonen aan dat de hoeveelheid training geen effect had op de gebruikte strategie: in beide trainingscondities richtte de helft van de proefpersonen zich op de diagnose van de conditieverslechtering, en de andere helft paste alleen behandelingen toe. De proefpersonen die goed getraind waren selecteerden echter meer diagnostische informatie en zij verwerkten de informatie sneller dan de groep die een beperkte training had gehad. Tijdsdruk verslechterde de integratie van informatie alleen voor de proefpersonen die slechts minimaal waren getraind.

De resultaten laten zien dat training alleen, dus zonder aanwijzingen over de manier waarop de taak aangepakt zou moeten worden, niet resulteert in het gebruik van een optimale strategie. Bovendien wordt aangetoond dat met een uitgebreide training de negatieve effecten van tijdsdruk voorkomen kunnen worden, met name voor wat betreft de integratie van informatie.

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1 INTRODUCTION

Even though many real-world decision tasks are of a dynamic nature, such as plant control, car driving or patient care, research has paid only little attention to the cognitive processes underlying dynamic decision making (Brehmer, 1992; Hammond, 1988).

One of the main characteristics of dynamic tasks, distinguishing them from the commonly used static tasks, is that the process to be controlled changes over time. This task feature implies that a decision maker not only has to decide how to react to system changes, but also when to react. Thus, when the operator in a power plant observes from his control panel a decline in system performance, he can react immediately, but he can also wait and observe the developments for a while, in order to determine the need for active interference.

Furthermore, dynamic environments often provide some global indication of system performance which can be used to evaluate the effects of executed actions. In other words, the decision maker receives feedback, which allows him or her to solve the problem incrementally, i.e. taking only small steps at a time (Hogarth, 1981). This possibility to receive feedback elaborates the set of decision strategies in dynamic situations with the so-called 'action-oriented' strategies (Kleinmuntz & Thomas, 1987): an action can be applied, its effect can be observed from the overall system performance, and if the desired improvement is not shown, the decision maker can continue with other actions until his or her goal is attained. Previous studies showed, however, that subjects preferred a 'judgment-oriented' strategy, even though an action-oriented strategy would have resulted in better performance: preceding the implementation of an action subjects first requested information in order to learn about the cause underlying the decline in system performance (Kerstholt, submitted; Kleinmuntz, 1985; Kleinmuntz & Thomas, 1987). Thus, in a dynamic environment subjects seem not to select the strategy that provides both the best outcome *and* which avoids the effortful information search and integration processes. This result contrasts with the overall conclusion of Payne, Bettman and Johnson (1993), who state that, to a large extent, decision makers make use of the environmental structure and select a strategy that performs fairly well in terms of the combination of effort and accuracy. One possible explanation for these opposing results is that adaptivity only concerns static tasks and well structured decision problems, and not dynamic tasks, which are in general somewhat more complex to deal with. Another possibility, which will be investigated in the present experiment, refers to the experience subjects have with the task. A prerequisite for adaptive responses is that people know the relation between strategy and task performance: the most efficient strategy can only be adopted when the effect of behavioral responses on outcome performance is known. In previous studies subjects received information on all relevant task parameters, but they only had minimal experience with the actual task. In the present study we manipulated the amount of training subjects received, and designed the task in

such a way that an action-oriented strategy would result in the best outcome performance.

I predicted that subjects who had received the more elaborate training, and would consequently be able to learn the relation between the use of a strategy and its outcome, would make use of the task dynamics, i.e. use an action-oriented strategy.

The changing nature of dynamic tasks implies that the time dimension is an important factor in the decision process. Not only do decision makers need to plan the time span of the diagnosis process and the time at which an action is applied, but they may also face time pressure when system performance deteriorates very rapidly. The effects of time pressure on decision making behaviour have mostly been investigated in static tasks, in which decision problems do not change over time (see for a review Svenson & Maule, 1993). Consistent findings from this line of research are that decision makers speed up information processing under time pressure, they request less information, they use a different kind of information, and they resort to less time consuming, simpler decision strategies (Edland & Svenson, 1993; Payne, Bettman & Johnson, 1988).

In previous experiments in which we used a dynamic task these findings were partly replicated, but the basic strategy, how subjects dealt with the task, did not change under time pressure, i.e. even when only limited time was available subjects used a judgment-oriented strategy. In these studies we used a within-subjects design: all subjects had to make decisions under various levels of time pressure. A possible drawback of using such a design is that subjects adopted a strategy that would result in reasonably accurate performance over all time pressure conditions. Thus, rather than planning different, optimal, strategies for each time pressure condition separately, subjects may have aimed at finding one global strategy that works reasonably well over all time pressure conditions. By using a between-subjects design, however, subjects would be able to select a strategy that would be optimal for the specific time span. Thus, on the assumption that individual subjects face only one type of time limitation, I predicted a strategy switch over different time pressure conditions.

A third research question concerns the interaction between training and time pressure. Many professional groups, such as fireground commanders and pilots, are well trained in procedures that should be used in crisis situations with high levels of time pressure (Means, Salas, Crandall & Jacobs, 1993). As a result of such an extensive training, decision makers may recognize the situation as belonging to a particular class, which will automatically trigger the appropriate procedures (Klein, 1993). A major advantage of such immediately applicable knowledge is that rapid decisions can be made, and unadaptive reactions due to stress can be avoided. Thus, unadaptive reactions to time pressure may be mediated by training: when a decision maker appraises his or her capacity or

knowledge as sufficient to deal with a particular task, negative effects of time stress may be overcome (Maule & Hockey, 1993). For the present experiment I predicted that performance would be less affected by high levels of time pressure when subjects were well trained as compared with subjects who did not have such an elaborate training.

2 METHOD

2.1 Subjects

Forty subjects voluntarily participated in the experiment. They were students at the University of Utrecht, and were paid Dfl. 45 for participation. A bonus of 10 guilders was given to the 5 best performing subjects.

2.2 The experimental task

Subjects were required to imagine that they were the personal attendant of an athlete who was running a race. The fitness level of this athlete was presented to the subjects by means of a graph on a computer screen (see Fig. 1). This information was constantly available to the subjects. The fitness level of the athlete could vary between 100 (optimal fitness level) and 0 (the athlete has collapsed).

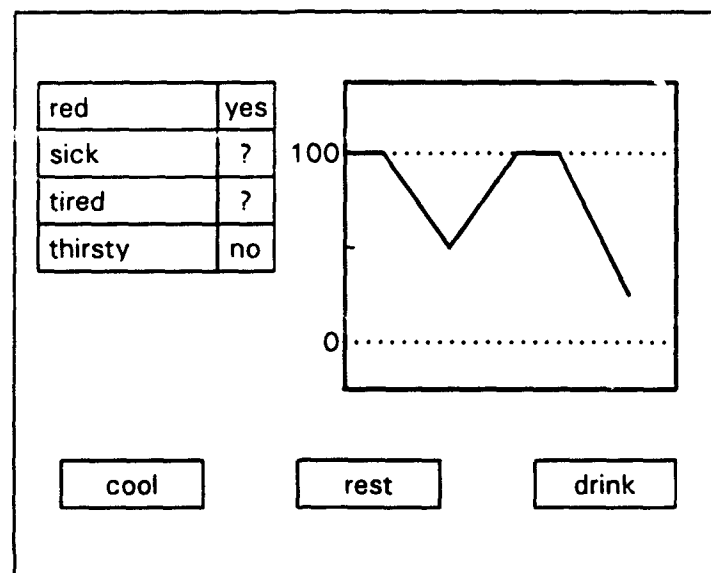


Fig. 1 Example of a computer screen that subjects faced in the experiment. The graph represents the athlete's fitness level, in the left window it can be seen that two information requests have been made, red and thirsty, and on the bottom the three possible actions are shown.

At several points in time the fitness level would start to decline, which could be due to four causes, a temperature problem, a circulation problem, a metabolism problem or a false alarm. A false alarm meant that the fitness level of the athlete declined without any physiological cause, i.e. a temperature, a circulation or a metabolism problem, and it would therefore recover spontaneously after some time (at a fitness level of 50). When the decline of the athlete's fitness level was caused by either a temperature, a circulation or a metabolism problem, on the other hand, the athlete's fitness level would decline until a collapse (fitness level of 0), assuming that nothing was done by the subject. The various causes of a decline occurred with different a priori probabilities: a temperature and a circulation problem occurred with a probability of .1, a metabolism problem with a probability of .3 and a false alarm with a probability of .5.

A decline was always prompted by a change in one parameter, multiple causes were excluded. Furthermore, the decline evolved linearly with its slope dependent on the time pressure condition. Thus, the graph that was shown on the computer screen provided information on the onset of a disturbance (the fitness level starts to decline) and over time, subjects would learn whether the decline was merely a false alarm (the athlete's fitness level spontaneously recovers) or was caused by a physiological disturbance.

Each cause resulted in a specific pattern of symptoms. The subjects could request this information in order to determine the specific cause underlying the fitness decline. The information requests were served by mouse clicks and the response was either 'yes' (the athlete has the symptom) or 'no' (the athlete does not have the symptom). The symptoms that could be requested were: red, feeling sick, tired, and thirsty. The probabilities of the occurrence of a symptom, given a particular cause were as follows (the probability of the symptom, given other causes $[p(S_i) | -H_j]$ is put in brackets):

	temperature	circulation	metabolism	no problem
red colour	0.9 (0.2)	0.1 (0.3)	0.2 (0.3)	0.2 (0.3)
feeling sick	0.2 (0.3)	0.8 (0.2)	0.5 (0.2)	0.1 (0.5)
tired	0.3 (0.5)	0.4 (0.5)	0.6 (0.5)	0.5 (0.5)
thirsty	0.3 (0.4)	0.2 (0.4)	0.7 (0.3)	0.3 (0.5)

If a decline was caused by a physiological disturbance the subjects needed to apply a treatment in order to prevent the athlete from collapsing. For each problem one specific action was needed:

in case of a temperature problem: to cool
 in case of a circulation problem: to rest
 in case of a metabolism problem: to drink

If the correct treatment was applied the fitness level would be restored, which could be deduced from a change in the curve from a decreasing fitness level to an increasing one.

2.3 Normative strategy: Monte Carlo simulations

A computer program was written that simulated two decision strategies: a judgment-oriented strategy and an action-oriented strategy.

Judgment-oriented strategy

For the judgment-oriented strategy the program started with considering all symptom information when the athlete's fitness level declined. Based on this information the a posteriori probability of each hypothesis was calculated, of a temperature problem, of a circulation problem, of a metabolism problem and of a false alarm. The program then selected the hypothesis with the highest probability. The selection of one hypothesis implied the application of one single treatment, which was then applied. If the treatment was correct the trial ended, and if the treatment was incorrect, i.e. the fitness level would continue to decline, the next, second best, hypothesis was selected, the appropriate treatment applied and its effect determined. This process continued until the athlete's fitness level spontaneously recovered (in the case of a false alarm), or when the correct treatment had been applied or when the athlete had collapsed.

Action-oriented strategy

For this strategy the program only selected treatments as a reaction to a fitness decline (in a fixed order: drink, cool, and rest). After applying a treatment its effect was determined, and if the fitness level was not increasing, the following treatment was applied. A trial would end when the fitness level spontaneously increased (in case of a false alarm), when the correct treatment had been applied or when the athlete collapsed.

These strategies were run in the task environment that has been described above.

The performance of both decision strategies was expressed by the overall money supply at the end of a run. Each time information was requested 0,50 guilder was deducted from the overall money supply, for the application of an action 1,0 guilders and for an athlete collapse 5 guilders. For a correct treatment 2,50 guilders were added to the money supply. Furthermore, it was simulated that an information request would take 1 second and that the selection of an action would take 5 seconds.

The simulations of both decision strategies were run 5000 times in 6 experimental conditions: the available time could either be 25, 12.5 or 8.3 seconds, and decision activities could either begin at a fitness level of 75 or at a fitness level of 50.

The results of these simulations are shown in Fig. 2 (mean amount of money per trial, corresponding to one fitness decline).

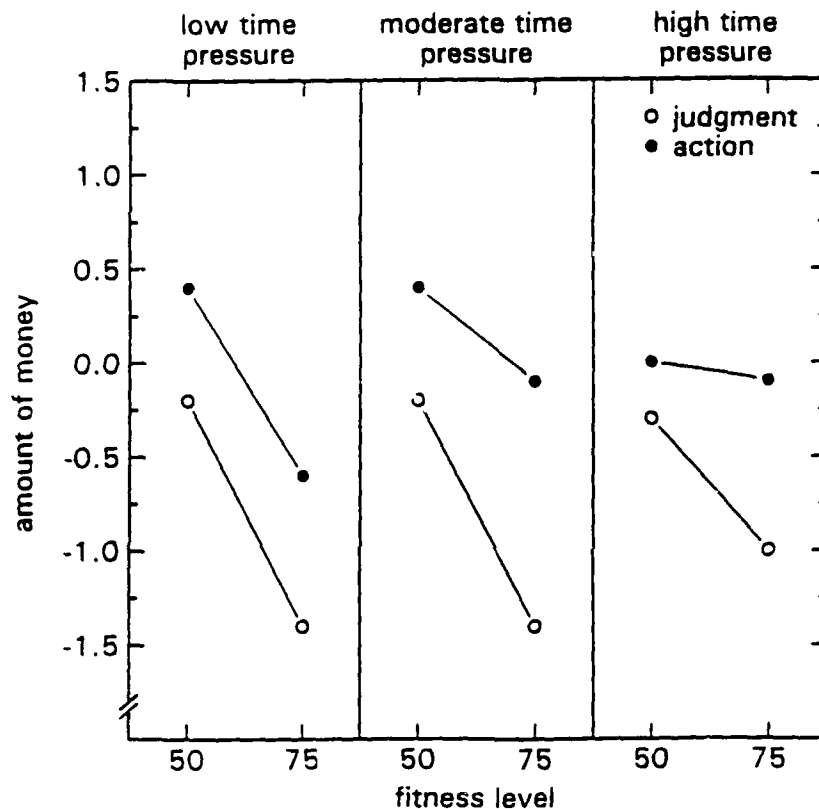


Fig. 2 Outcome (mean amount of money per trial) of the Monte Carlo simulations, for the judgement-oriented and the action-oriented strategy, which could be applied at a fitness level of either 50 or 75, in three time pressure conditions (low, moderate and high).

In each time pressure condition the action-oriented strategy resulted in better performance: the expected benefit per trial is higher. Furthermore, it appears to be more advantageous to wait until a fitness level of 50, rather than to start with interference at a fitness level of 75. Thus, it can be concluded from these simulations that in this specific task, it would be optimal to start interference at a fitness level of 50, and to apply actions only. The results of the simulation are to some extent dependent on the selection of the times for an information request and the application of a treatment. Note, however, that the simulations scheduled 5 seconds for the application of an action and only 1 second for an

information request, which implies that the chosen times formed already a disadvantage to the action-oriented strategies.

2.4 Procedure

The experiment was divided into three parts: two training sessions and the actual experiment. In the first training session subjects had to learn the relations between combinations of symptoms and the most probable causes. This training was the same for each subject. They were given the information on a priori probabilities, on the probabilities of symptoms given the possible causes of the decline, $[p(S_i | H_j)]$, and on the probabilities of the symptoms given other possible causes of the decline, $[p(S_i | -H_j)]$. The information on symptom/-hypothesis relations was presented in eight bar-plots. Fig. 3 shows an example of such a plot for one of the symptoms (red colour). Subjects interacted with a computer program that presented them with random combinations of symptoms (for example, "not red, not sick, thirsty and tired"). The subject had to select the most probable cause given the symptoms. After each trial they were given feedback on the accuracy of their diagnosis and in case of an incorrect diagnosis they were also told which one should have been selected. After each run of 10 trials the subject was given feedback on his or her overall score of the run. The general learning criterion was three successive runs comprising two runs that were 100% correct.

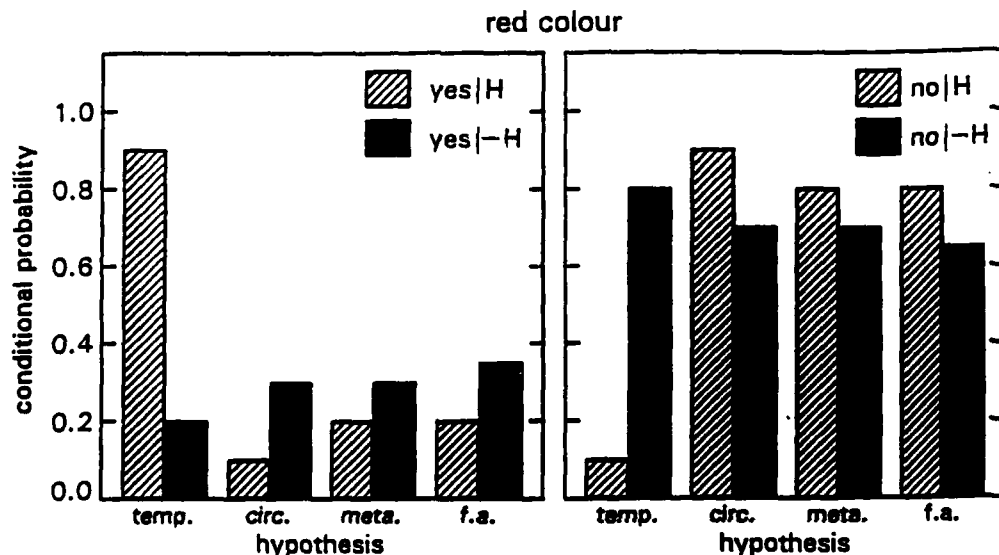


Fig. 3 Information provided to the subjects indicating the relations between symptoms and possible causes of a fitness decline.

After learning the relations between symptoms and underlying causes, the subjects continued with the training of the actual task. This training session comprised two conditions, a minimal training condition and an elaborate training condition. Half of the subjects practised the task for 15 minutes without

receiving feedback on the effects of their actions on the overall money level. The other half of the subjects went through an elaborate training session: they practised for 30 minutes and were continuously given information on the overall money supply. This way, they could learn the effect of the used strategy on their goal to end with the highest possible amount of money. The subjects started off with an amount of Dfl. 100.-. They paid Dfl. 0.50 for one information request, Dfl. 1 for the application of a treatment, and Dfl. 5 for an athlete collapse. They received Dfl. 2.50 whenever they restored the athlete's fitness level correctly.

2.5 Design

A 2*2 (time pressure, training) factorial was used. Time pressure was manipulated by the slope of system decline. It was a between subjects factor, each subject was in either the slowly changing condition or in the quickly changing condition. There were two time pressure conditions: low time pressure (slope of -4, implying that the athlete's fitness level would decrease in 25 seconds from 100 to 0) and high time pressure (slope of -12 or 8.3 seconds). Furthermore, half of the subjects received the short training and the other half of the subjects received the elaborate training.

The subjects were presented with 30 fitness declines in each time pressure condition. Half of these declines were caused by false alarms. After a correct treatment was applied the fitness level would increase to a value of 100 and the next trial would start.

Dependent variables

Timing, is indicated by the time span between the onset of a fitness decline and the first information request or action. Since I am interested in a strategic effect, I will consider the relative time, i.e. the absolute time divided by the available time.

Decision strategy, is indicated by the ratio between the number of times information was requested after the onset of a fitness decline and the number of times a treatment was applied immediately after the onset of a decline.

Information search, is indicated by the *number of information requests* and the *kind of information requests*. In order to investigate the quality of the requested information we calculated the uncertainty reduction with respect to the underlying causes (H_j) that would be realised when each of the symptoms (S_i) was requested. The following formula was used (Dretske, 1981):

$$\sum_{j=1}^4 [(H_j|S_i) * \log_2 \left(\frac{1}{(H_j|S_i)} \right)]$$

This formula was applied for both the situation where the symptom would be absent and the situation where the symptom would be present. The overall value was attained by weighing the amount of information by the probability of the symptom being respectively absent or present. The uncertainty remaining after knowing the outcome for one symptom (the one first requested) was 1.48 bits for the symptom 'sick', 1.53 bits for the symptom 'red', 1.56 bits for the symptom 'thirst' and 1.66 bits for the symptom 'tired'. Thus, from these data it can be inferred that the symptom 'sick' reduces most uncertainty, and it would therefore be optimal to request this symptom first.

Information integration is indicated by the difference between the probability of the chosen option given the requested information and the probability of the best option given the requested information. Thus, when the best option given the requested information is selected, this value is 0.

Processing time: time span between last information request and the selection of a treatment. In this time span subjects have to combine the symptom information, deduce the most probable cause of the decline and implement an action.

Performance is indicated by the overall money level at the end of the experiment, reflecting the trade-off between the costs and the risk of athlete collapse and by the number of correct athlete recoveries.

3 RESULTS

3.1 Learning the relations between symptoms and causes

All subjects were able to learn the relations between symptoms and causes (mean number of trials was 205 ($s=53.7$), and the mean score in the last run was 97.3 ($s=6.4$)).

The development of the learning process is shown in Figure 4.

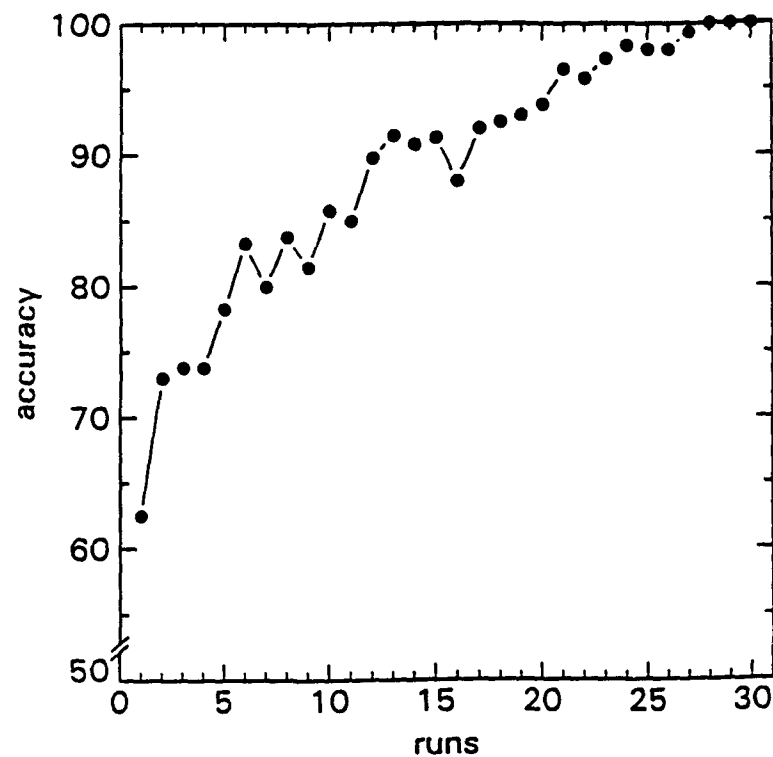


Fig. 4 Learning curve expressing the percentage correct trials over successive runs. A run comprises ten judgements of symptom combinations.

3.2 Experimental data

Timing

The relative times (time until interference divided by the total amount of time available) were affected by the amount of time pressure that was imposed on the subjects ($F(1,36)=7.70$, $p<.01$, see Figure 5): under high levels of time pressure subjects started to interfere sooner with the athlete. The amount of training did not affect the moment of interference ($F(1,36)<1$).

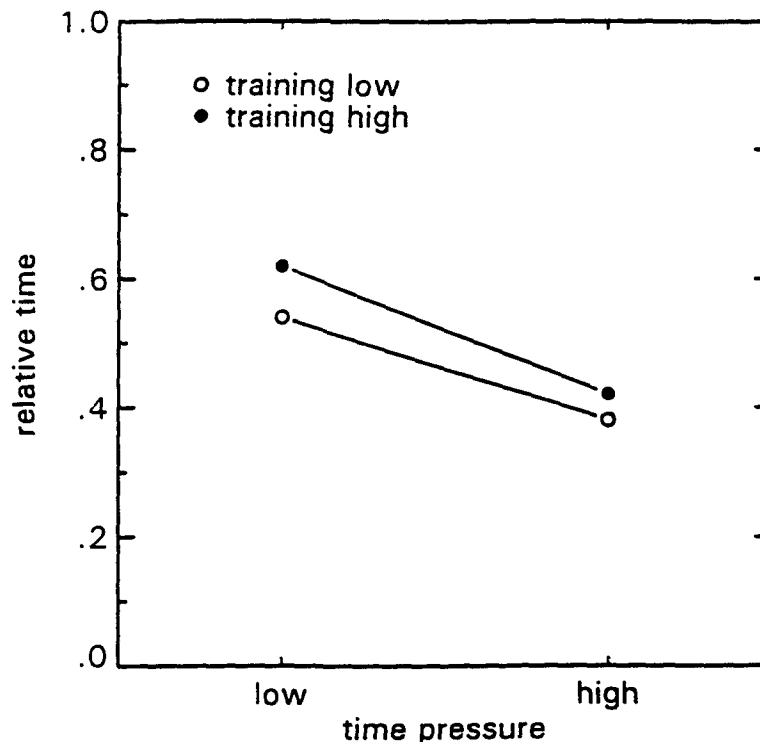


Fig. 5 Relative time that subjects waited after the onset of a fitness decline before interference by either an information request or an action as a function of time pressure (low or high) and training (low or high). The relative time is the time subjects waited divided by the total amount of time available.

Decision strategy

Action- and judgment-oriented strategies were used equally often by the subjects and were not affected by time pressure ($F(1,36) < 1$, proportion action-oriented strategies was .50 in the low time pressure condition and .50 in the high time pressure condition) and by the amount of training ($F(1,36) < 1$, proportion action oriented-strategies was .47 in the low training condition and .53 in the high training condition). Seven (of the 20) subjects in each training condition did not request information at all, and therefore used a straight action-oriented strategy, and seven subjects in the low training condition and nine subjects in the high training condition always started to request information after the onset of a fitness decline, i.e. used a judgment-oriented strategy. The rest of the subjects used a combination of both strategies over the different trials.

Information search

Subjects requested an equal amount of information in all experimental conditions (time pressure: $F(1,36) < 1$, training: $F(1,36) = 1.26$, $p > .2$). Table I shows the proportion of symptoms that were first requested after the onset of a decline, which provides an indication for the accuracy of the selected information.

Table I Symptoms that were requested first after the onset of a fitness decline as a function of time pressure (low or high) and training (low or high).

	time pressure low		time pressure high	
	training low	training high	training low	training high
red	.32	.06	.27	.14
sick	.34	.62	.44	.66
tired	.12	0	.16	.03
thirsty	.23	.32	.14	.16

The various symptoms were not equally often requested ($F(3,66)=7.4$, $p<.0001$), and from the table it can be inferred that subjects mostly requested the symptom 'sick'. A marginally significant interaction was found between the kind of information requested and the training condition ($F(3,66)=2.5$, $p=.07$): subjects who had a more elaborate training requested the symptom 'sick' more often, implying a more optimal information selection process. Overall, this result indicates that subjects were well aware of the value of the various symptoms, since they mostly selected the symptom that would reduce most uncertainty (sick).

Information integration

No main effects of training ($F(1,36)<1$) and time pressure ($F(1,36)=2.69$, $p>.1$) were found on the accuracy of the integration of information, only a marginal interaction between time pressure and training ($F(1,36)=3.63$, $p=.07$, see Figure 6). Subjects who had only limited training performed worse when time pressure increased.

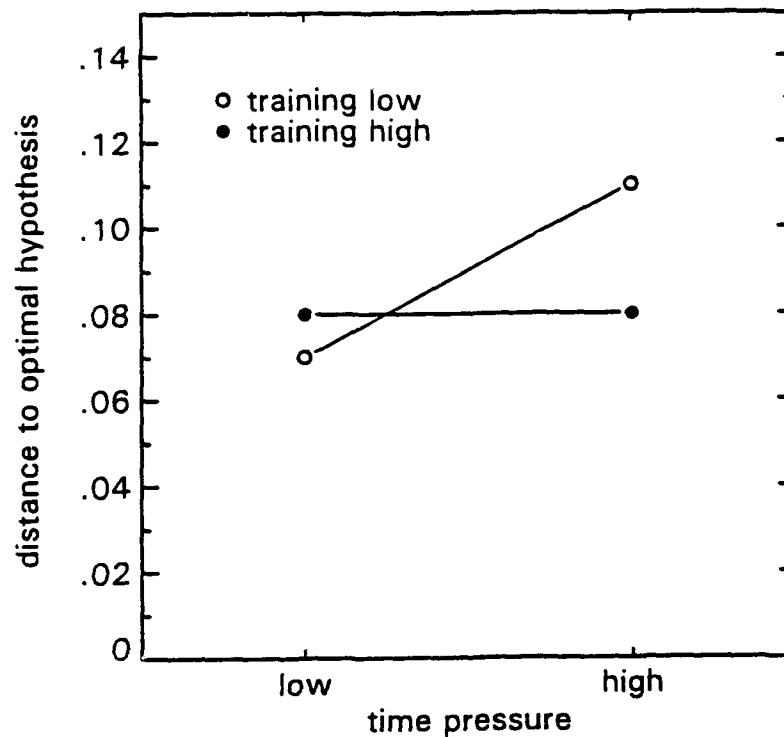


Fig. 6 Distance between chosen hypothesis and optimal hypothesis (as indicated by the a posteriori probability) as a function of time pressure (low or high) and training (low or high). A value of 0 means, that the optimal hypothesis, given the requested information, was chosen.

Processing time

Subjects who experienced more time pressure were faster than the subjects who experienced less time pressure ($F(1,22)=10.96$, $p<.005$), and subjects who had elaborate training were faster than the subjects with only limited training ($F(1,22)=4.45$, $p<.05$, see Figure 7). Note that only subjects who had requested information could be used for this analysis, meaning that 7 subjects in each training condition were excluded.

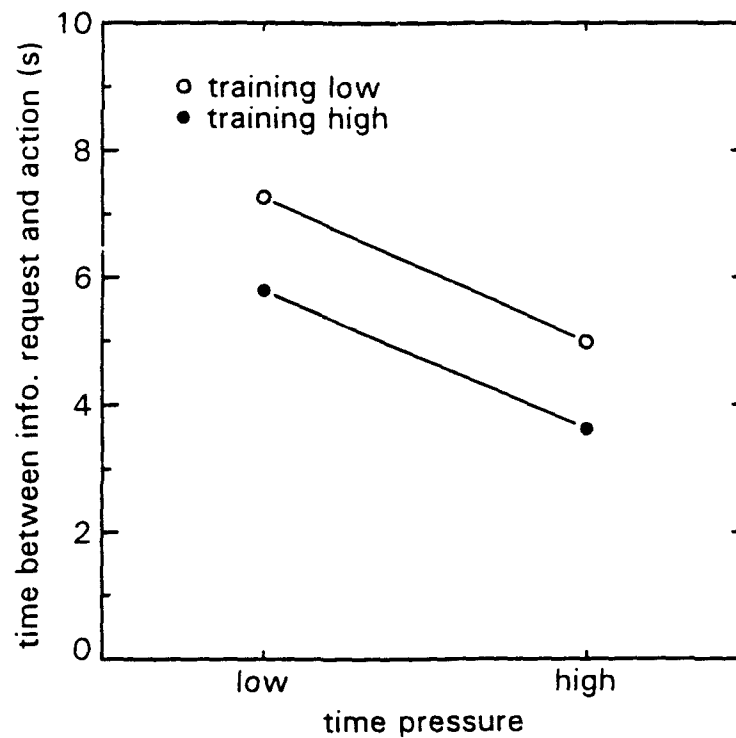


Fig. 7 Time span (in seconds) between the last information request and the succeeding action as a function of time pressure (low or high) and training (low or high).

Performance

Subjects who were more extensively trained earned more money than the subjects with less training ($F(1,36)=4.56$, $p<.05$, 97 guilders versus 84 guilders). Thus, with more training subjects made better trade-offs between the various costs and risks on athlete collapse. It did not matter whether subjects experienced high or low time pressure ($F(1,36)=2.82$, $p>.1$).

Under a low level of time pressure more athletes were recovered than under a high level of time pressure ($F(1,36)=6.46$, $p<.05$, see Figure 8), and the well-trained subjects made more correct athlete recoveries than the subjects with only minimal training ($F(1,36)=5.8$, $p<.05$).

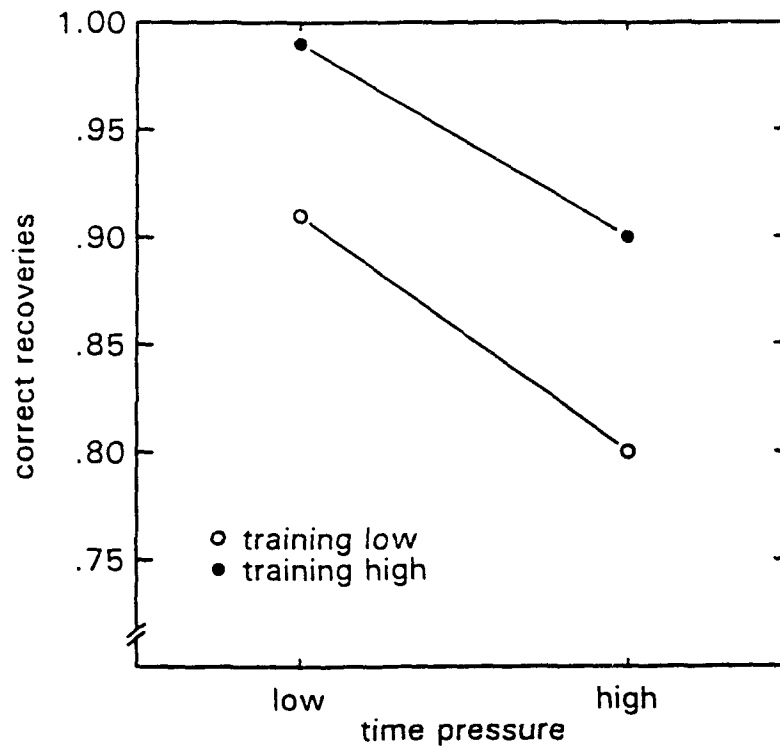


Fig. 8 Proportion correct recoveries, meaning that fitness declines due to physiological causes were correctly restored, as a function of time pressure (low or high) and training (low or high).

4 DISCUSSION

In contrast with my prediction, training did not affect the decision strategy that was dominantly used: in both training conditions about 50% of the subjects used an action-oriented strategy, and the other half used a judgment-oriented strategy. As the use of an action-oriented strategy would lead to optimal performance, with minimal effort, this result implies that subjects did not adaptively react to the task dynamics. Half of the subjects in the present experiment received quite extensive training, and continuous feedback, but they still used the same strategies as the subjects who did not have such an elaborate training. Insufficient experience with the task seems therefore no plausible explanation for the use of less than optimal strategies.

Rules for the selection of an appropriate strategy for performing a task are referred to as 'metastrategies', specifying how one decides to tackle the problem at hand. One possibility, which could be put forward as an explanation for the rather consistent use of a judgment-oriented strategy, is that the global task features trigger a general class of strategies. Diagnosis tasks, which I also used in

the present experiment, could then well be associated with a general class of 'infer-than-act' strategies (Kleinmuntz and Thomas, 1987). Thus, it is suggested that the general strategy is based upon the global task characteristics and that adaptivity occurs within the constraints of this strategy, such as speeding up processing or limiting the number of information requests.

Still, the number of subjects using an action-oriented strategy was considerably higher than in our previous experiments, in which judgment-oriented strategies were used in about 75% of the trials (Kerstholt, submitted). Two reasons may explain this difference. First, the training program for learning the relations between symptoms and causes was changed, such that the subjects in the present experiment received both feedback on the accuracy of their chosen option with respect to the requested information, i.e. the a posteriori probability, and on the accuracy of the chosen option with regard to the actual reason of the decline. In the previous experiments the subjects only received feedback on the accuracy with regard to the a posteriori probability. Providing both forms of feedback allowed the subjects to experience the limitations of the value of the information: even when they knew all symptoms and deduced the most optimal hypothesis, the athlete could still suffer from a different disorder.

Second, in the previous experiments subjects only received a minimum number of trials to familiarize themselves with the experimental task. As a matter of fact, it was left to the judgment of the experimenter to determine the moment the actual experiment would start, depending on the abilities of the subjects. In the present experiment, however, subjects trained at least 15 minutes. Even though these subjects did not receive feedback on the money that had been earned, they did receive feedback on the accuracy of their actions by observing the athlete's fitness level. This information may have been sufficient for subjects to partly switch to an 'action-oriented' strategy.

Even though strategy selection appears to be independent from the amount of training, subjects with more elaborate training had a better outcome performance, such that they ended with a larger amount of money at the end of the experimental session. As noted above this difference cannot be ascribed to the selection of a different strategy. Rather, the differences appear at a lower behavioral level: more training resulted in more accurate information search and faster processing. The amount of training did not affect the accuracy of information integration. In a recent overview of information use by experts, Shanteau (1992) concluded that research consistently indicated that experts used as much information as novices. He suggested, therefore, that it is the kind of information that distinguishes experts from novices, rather than the amount of information (see also Johnson, Duran, Hassebrock, Moller, Prietula, Feltovich and Swanson, 1981, for a similar conclusion). This suggestion is supported by the present findings: even though the subjects in both training conditions requested the same amount of information, the well-trained subjects selected more diagnostic information, as indicated by the amount of uncertainty reduction.

The time pressure effects replicate previous findings: when there was less time for diagnosis subjects reacted sooner to a fitness decline (Kerstholt, submitted), they used the same decision strategy (Kerstholt, in press, submitted) and they speeded up information processing (Edland and Svenson, 1993; Kerstholt, submitted; Payne, Bettman and Johnson, 1988). An explanation for the absence of strategic effects in previous experiments using an within-subjects design could have been that subjects had learned a strategy that would marginally fit all time conditions. Note, however, that we used a between-subjects design in the present experiment, implying that subjects could select the strategy that would optimally fit one single time condition. As the same strategy was used in each time condition when using a between-subjects design, we may conclude that a strategy switch is not in the behavioral repertoire to respond to time pressure, and that the absence of time pressure effects on strategy selection is not due to the use of a within-subjects design.

Subjects who had only limited training performed less well when time pressure increased than subjects who had had an extensive training: they applied more incorrect treatments. This performance deterioration for the less well trained group was due to less accurate information integration processes. Thus, information search remains constant for both training groups over time pressure conditions, but the integration processes deteriorated for the subjects who had only limited training. The computational requirements for the integration of probabilistic information into one overall judgment of the situation provides a heavy load on working memory, which is generally considered as a system with limited capacity. Thus, the present results suggest that in addition to the deteriorating effects of stressors such as anxiety (Hockey, 1986), time pressure affects task components with a high working memory demand as well. These deteriorating effects can be overcome, however, with training. Plausibly, training reduces the working memory load as processing is shifted towards preprogrammed procedures, or in other words decision making may become more recognition primed (Klein, 1992).

To conclude, the results of the experiment showed that training does not affect the overall strategy that subjects used for the decision task. However, subjects with more extensive training performed better, which was due to more accurate information search processes and to faster processing. In line with previous findings subjects did not change their decision strategy as a consequence of time pressure, even though a between-subjects design was used in the present experiment. Furthermore, elaborate training can make the integration of information more resistant to negative effects of time pressure.

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A handwritten signature in dark ink, consisting of several overlapping, sweeping strokes that form a stylized, somewhat abstract representation of the name.

Drs. J.H. Kerstholt

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